Energy Efficient Technologies Screening Process

A Simulation-Based Approach

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Overview

- Objectives
- Scope of Simulation Study
- Scripting Tools
- Post-Processing Simulation Results
- Application of Results

Objectives

- Develop simulation-based tools to facilitate evaluation of energy conservation measures and technologies.
  - Provide a quantitative evaluation of promising technologies.
  - Provide a platform for discussion of new technologies.

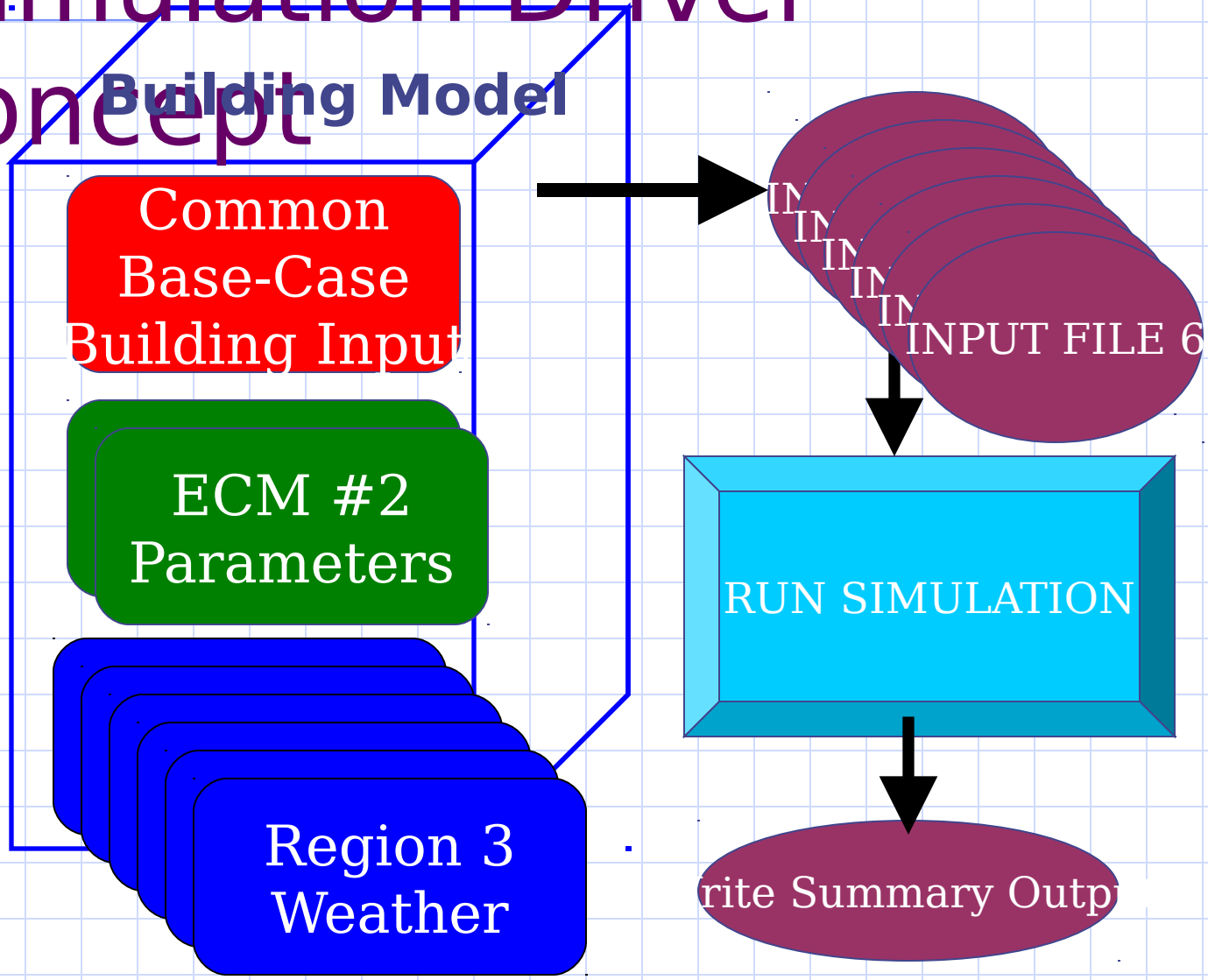
Approach

- Develop typical building models in two simulation environments.
- Program ‘simulation drivers’ to automatically:
  - build input files
  - run the simulation
  - retrieve simulation results
  - write a summary file

Current Scope

- Industrial building model
  - 20 Energy conservation measures and technologies.
  - 12 climates
  - 3 energy cost levels
- Office and barracks models
  - 40 energy conservation measures and technologies
  - 12 climates
  - 3 energy cost levels

‘Simulation Driver’ Concept



‘Simulation Driver’ Advantages

- Extensible
  - new technologies.
  - additional climates.
  - different energy costs.
- Verifiable
  - Codifies inputs for expert evaluation.
  - Facilitates replication of simulation results.
- Maintainable
  - Input parameter changes are seamlessly propagated to simulation results.

Post-Processing

- Summary Output file:
  - 1 data record per simulation
  - Standard Excel file (csv)
- Output Report Template
  - ‘Copy & Paste’ in Standard output sheet
  - Generate/update all ECM tables and plots

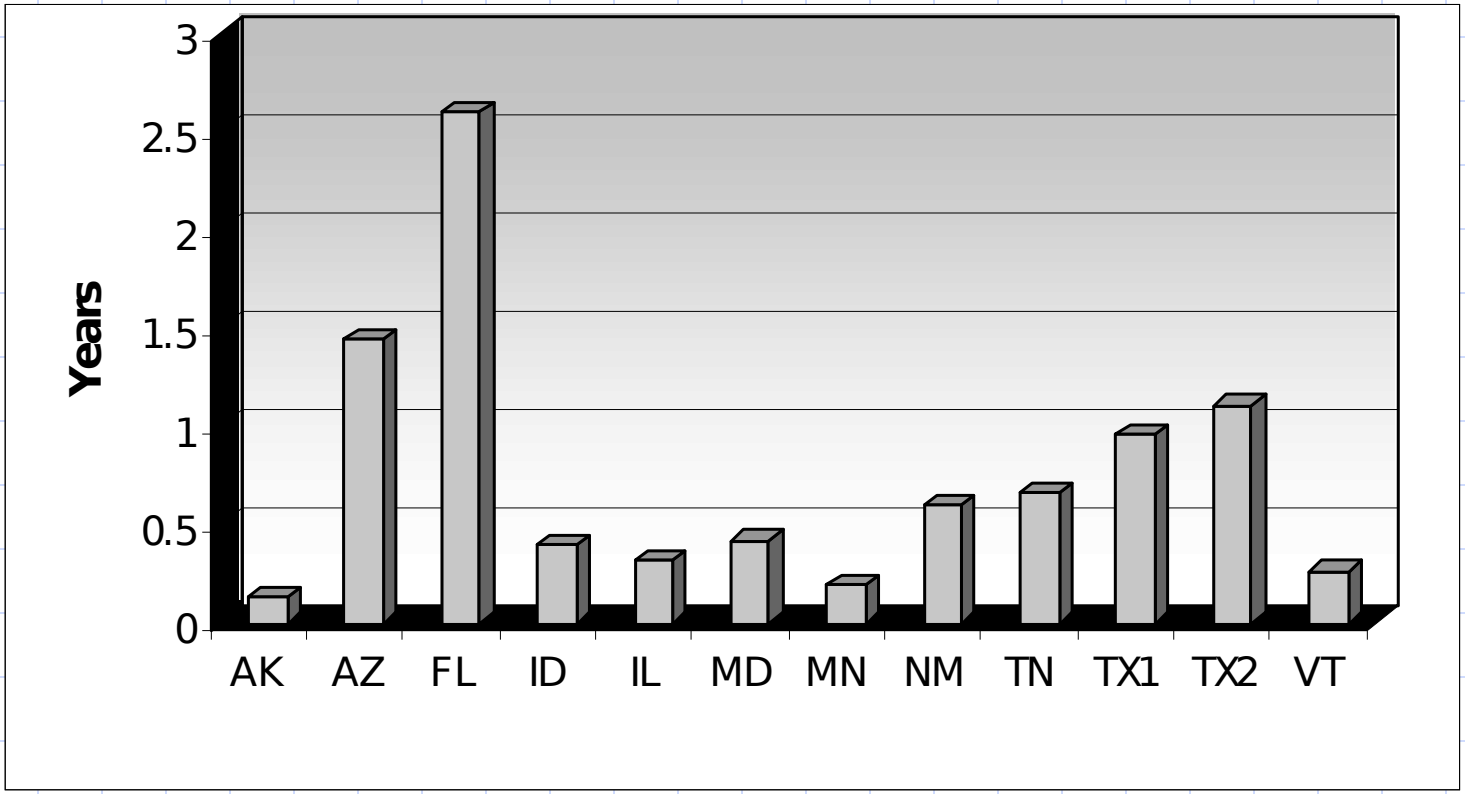
Post-Processing: Reports

- Report Data
  - Annual Electricity Savings [Kw-hr]
  - Annual Gas Savings [Therms]
  - Annual Elecricity Savings [$]
  - Annual Gas Savings [$]
  - Change in initial cost [$]
  - delta maint. cost [$]

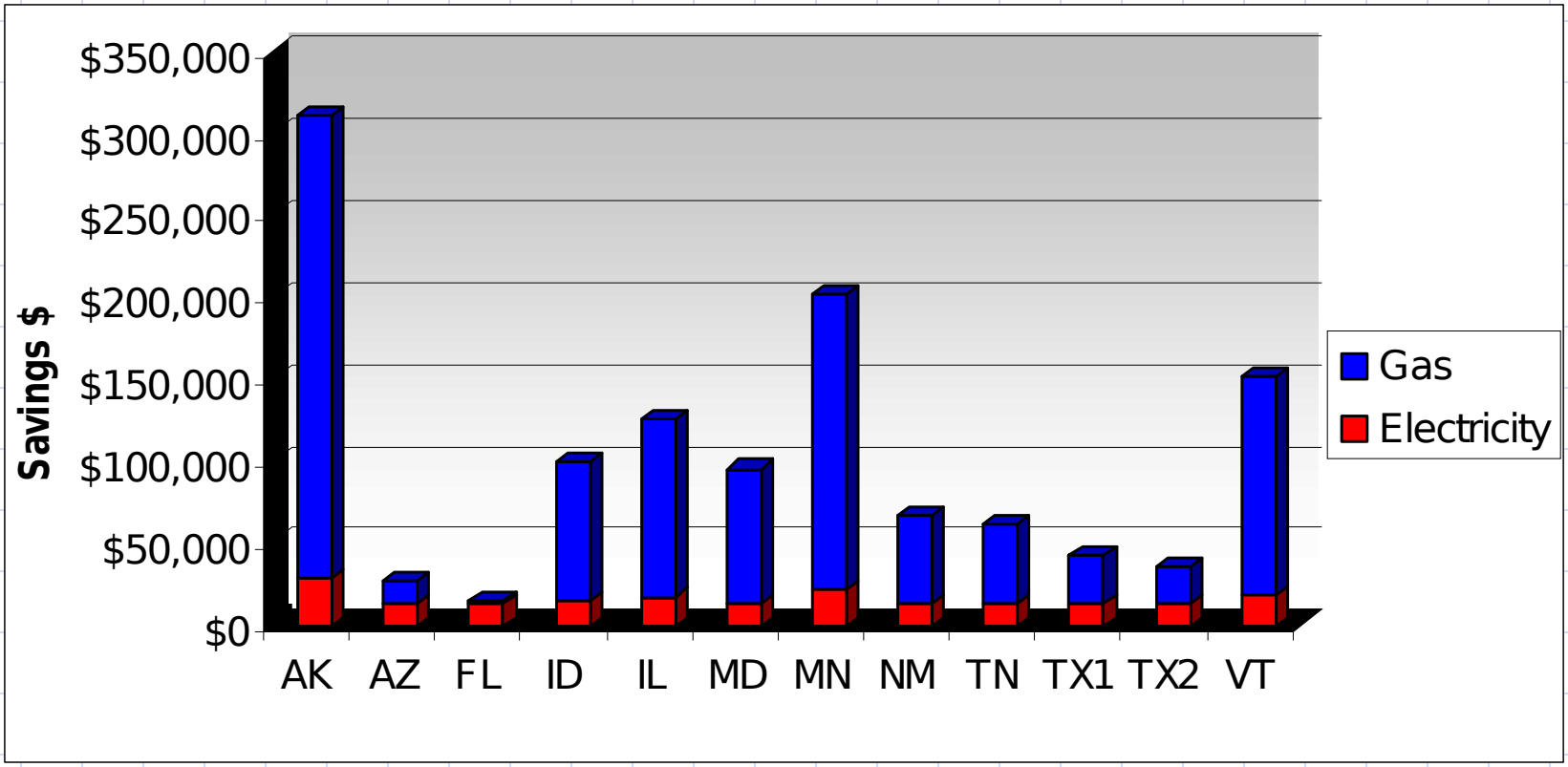
Standard Output Format

- Simple payback chart
- Energy savings chart
- Simulation results table

Simple Payback



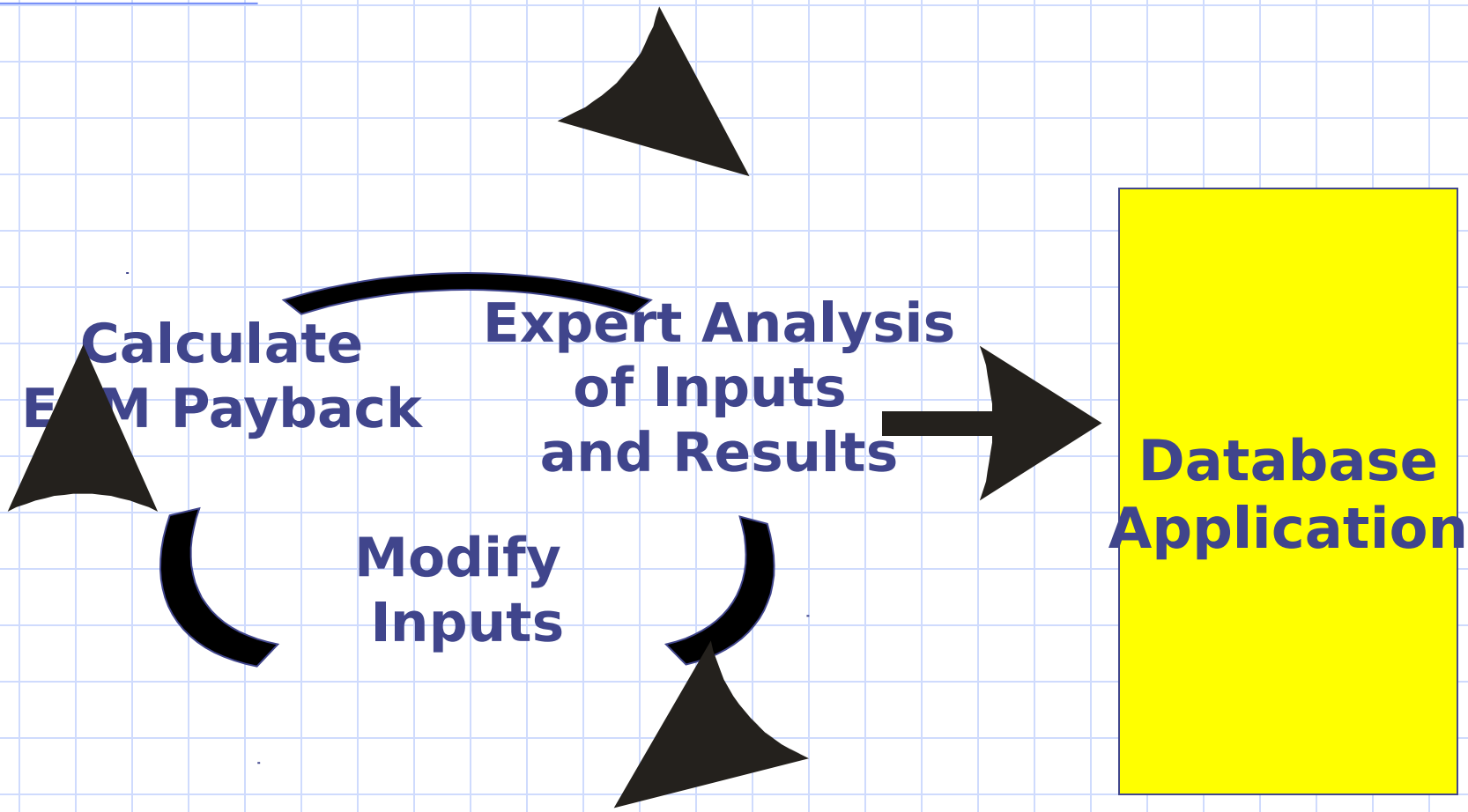
Energy Savings



Simulation Results

Location	Annual Electric Savings [KW]	Annual Gas Savings [Therms]	Electric Cost [$/KW]	Gas Cost [$/Therm]	First Cost [$]	Mainten-ance Cost [$]
AK	295726.3	351244.5	$0.10	$0.80	$40,275	$0
AZ	134215	18042.41	$0.10	$0.80	$40,275	$0
FL	134117.4	2566.7	$0.10	$0.80	$40,275	$0
ID	145088.1	106954.4	$0.10	$0.80	$40,275	$0
IL	178123.4	135475.6	$0.10	$0.80	$40,275	$0
MD	140619.1	101810.4	$0.10	$0.80	$40,275	$0
MN	223295.6	225087.4	$0.10	$0.80	$40,275	$0
NM	139491.8	65757.45	$0.10	$0.80	$40,275	$0
TN	138575.6	59003.31	$0.10	$0.80	$40,275	$0
TX1	135631.1	35701.36	$0.10	$0.80	$40,275	$0
TX2	134192.8	28567.75	$0.10	$0.80	$40,275	$0
VT	182725.8	166556.9	$0.10	$0.80	$40,275	$0

Application of Results



Conclusions

- Developed a simulation-based screening process for energy efficient technologies.
- The process generates cost and simple payback data for each ECM.
- The process facilitates incorporation of feedback from ECM experts.

Energy Efficient Technologies Screening Process

Building and System Models

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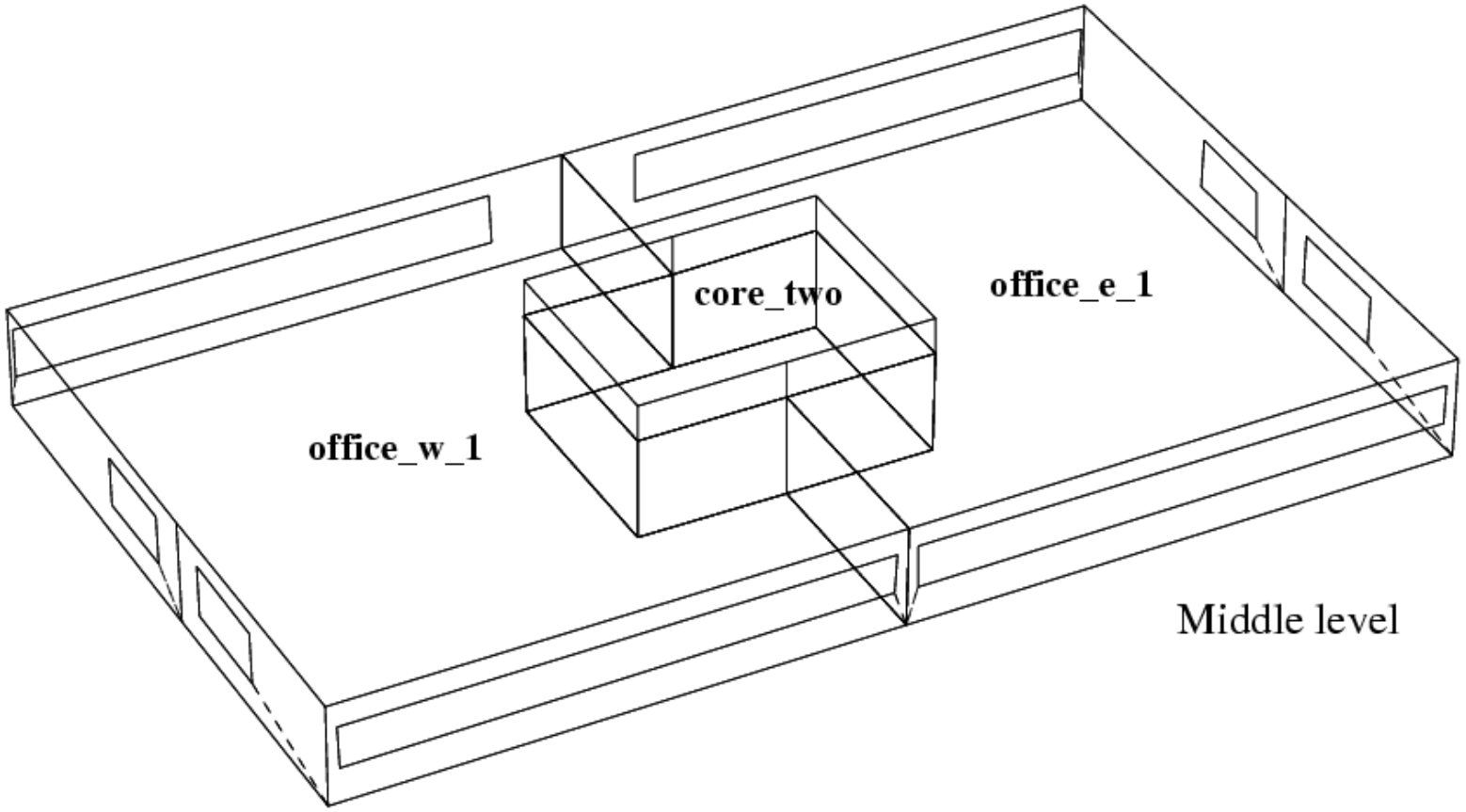
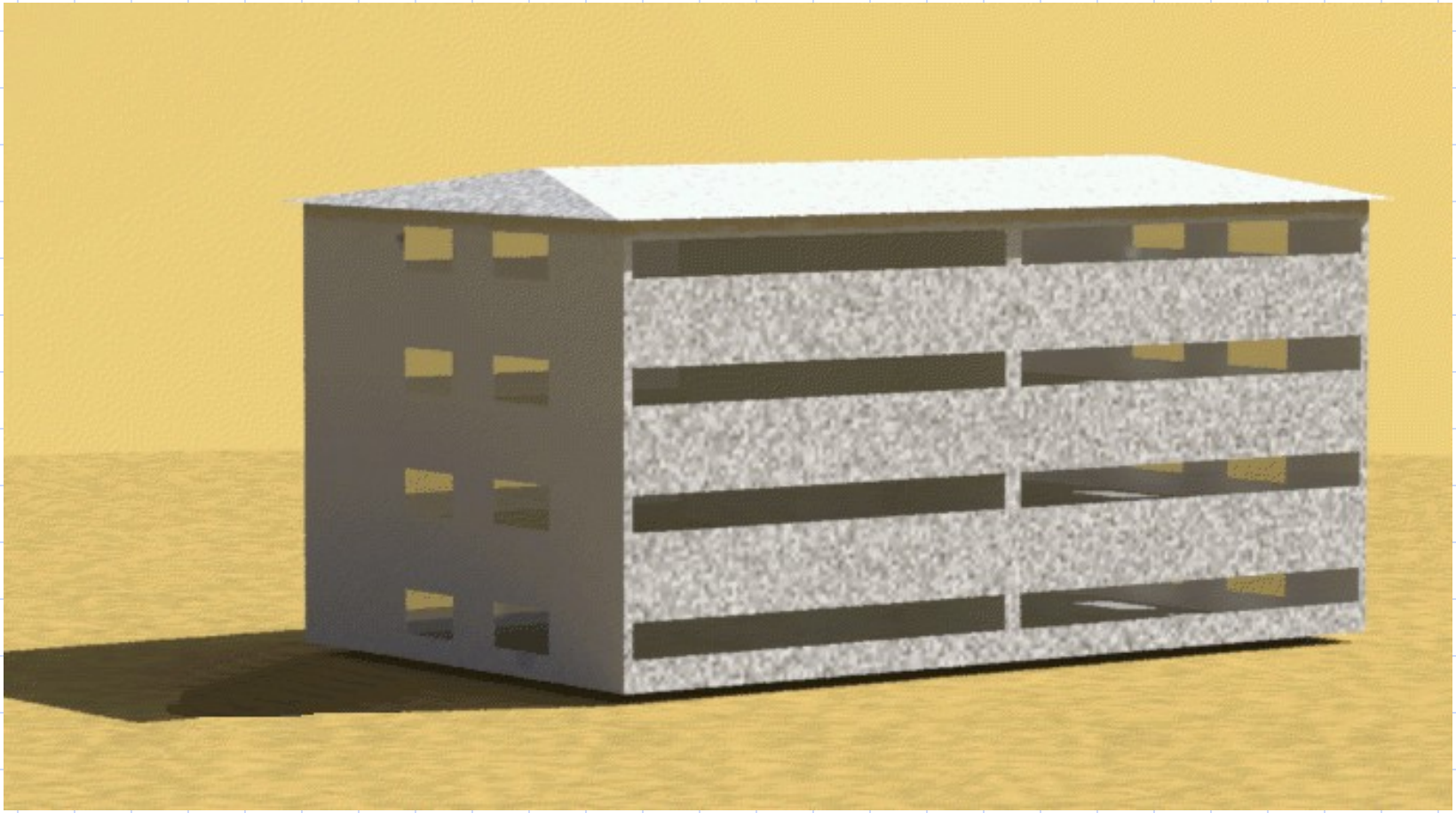
Overview

- Non-industrial building models
- Energy conservation measures and technologies
- Results:
  - Qualitative analysis
  - Quantitative analysis

Office Model



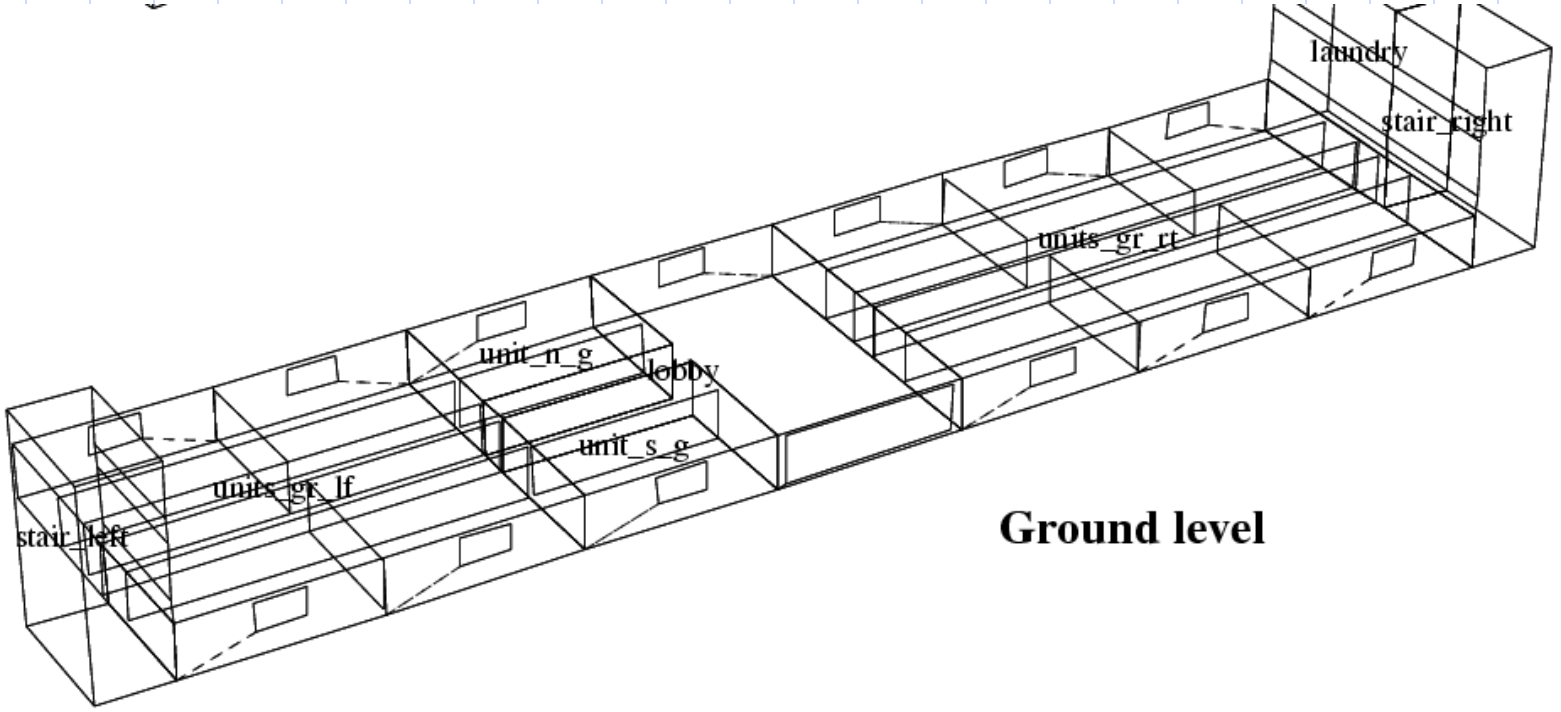
Office Model



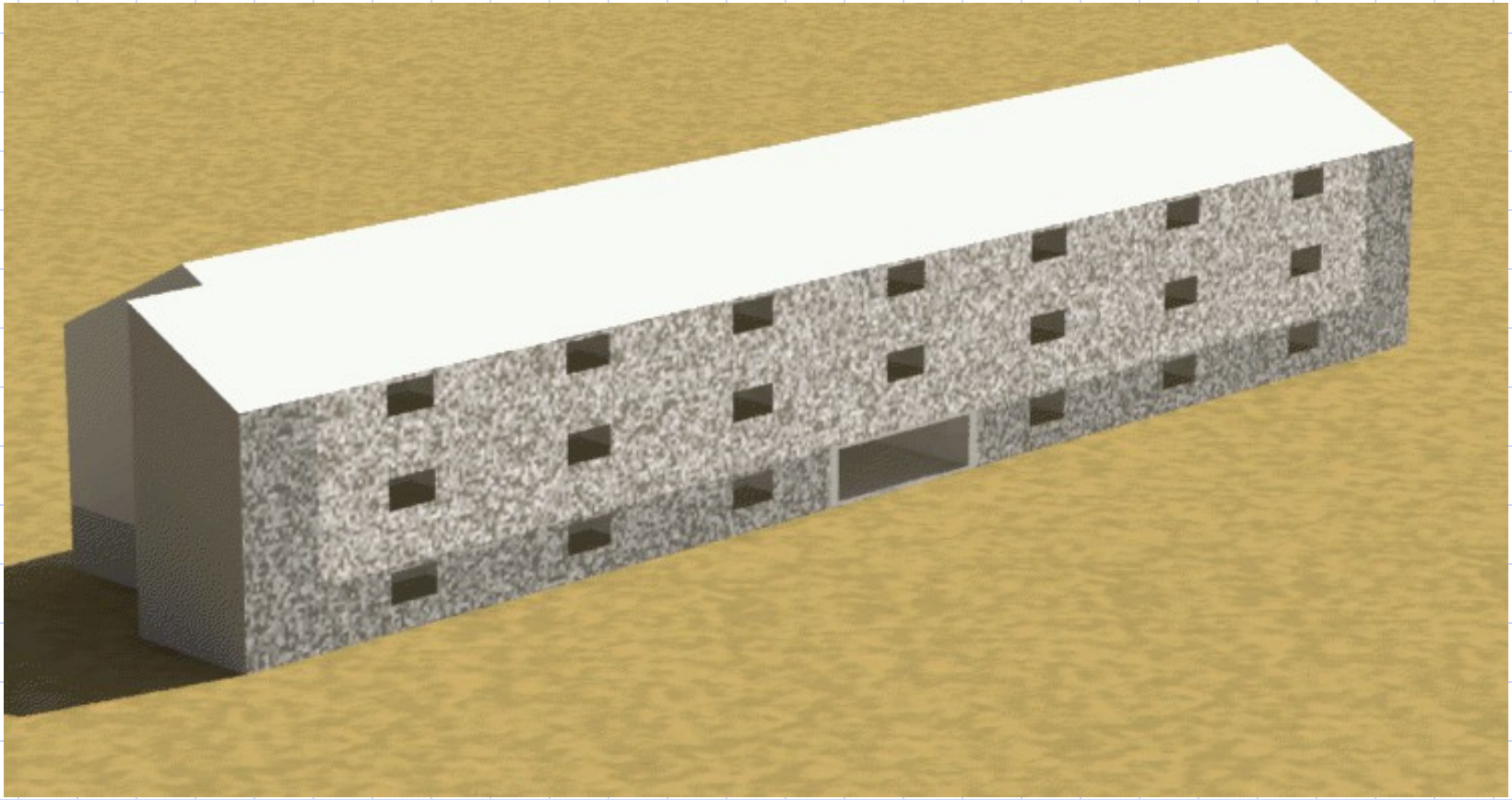
Office Specifications

Building Type	Administrative
Function	Office
Size (sqft) Total	23248 ft^2
Zones	16 zones
1st Floor	5812 ft^2
2nd Floor	5812 ft^2
3rd Floor	5812 ft^2
4th Floor	5812 ft^2
Stories	4 stories
Height	~50' total building height
Aspect Ratio	98.4' by 59.05' or 30m by 18m
Orientation	E-W

Barracks Zoning



Barracks



Barracks Specifications

Building Type	Barracks
Function	Housing
Size (sqft) Total	29148 ft^2
Zones	19 zones
1st Floor	9716 ft^2
2nd Floor	9716 ft^2
3rd Floor	9716 ft^2
Stories	3 stories
Height	~33' total building height
Aspect Ratio	196' by 48' or 59.74m by 14.63m
Orientation	E-W

Internal Heat Gains

- Office
  - ~1 W/ft2
  - Occupied from 8:00 am – 5:00 pm
- Barracks
  - ~0.7 W/ft2
  - Occupied from 8:00 pm – 5:00 am

Facade

- Office
  - Double pane windows; 32% of façade area
  - Brick/block construction
- Barracks
  - Double Pane windows; 10% of façade area
  - ‘Stick-frame’ construction

HVAC System

- Office
  - VAV with CW cooling and HW reheat
  - Cooling 75; heating 72
- Barracks
  - CV with DX cooling and gas reheat
  - Cooling 75; Heating 72

Energy Conservation Measures

- Building and environment
- Mechanical system
  - Controls
  - Radiant equipment
  - Air-handling equipment
  - Plant equipment
  - Maintenance
- Internal heat gain

Building and Environment ECMs

High performance windows
Operable windows
Solar wall for outdoor air preheating
Cool roofs
Roof insulation
Attic insulation
Insulated and sealed doors
Vestibules
Exterior light shelves
Exterior vertical fins
Roof Spray Cooling
Skylights or solar tubes
Detached window shading (trees)
Windbreaks

Mechanical System ECMs

Controls
Setback thermostats
Night pre-cooling
CO2 sensors
Hybrid (mechanical/natural) ventilation
Radiant Systems
Hydronic heating with convectors
Radiant Floor heating
Hydronic radiant heating and cooling panels

Mechanical System ECMs

Air Handling Equipment
Ventilate attic
Separate A/C and ventilation system (DOAS)
Displacement ventilation
Replace window A/C with central air system
Replace window A/C with Dx split system
Heat pipe heat recovery
Enthalpy wheel heat recovery
Indirect evaporative coolers
Direct evaporative coolers
Replace motors with high efficiency motors

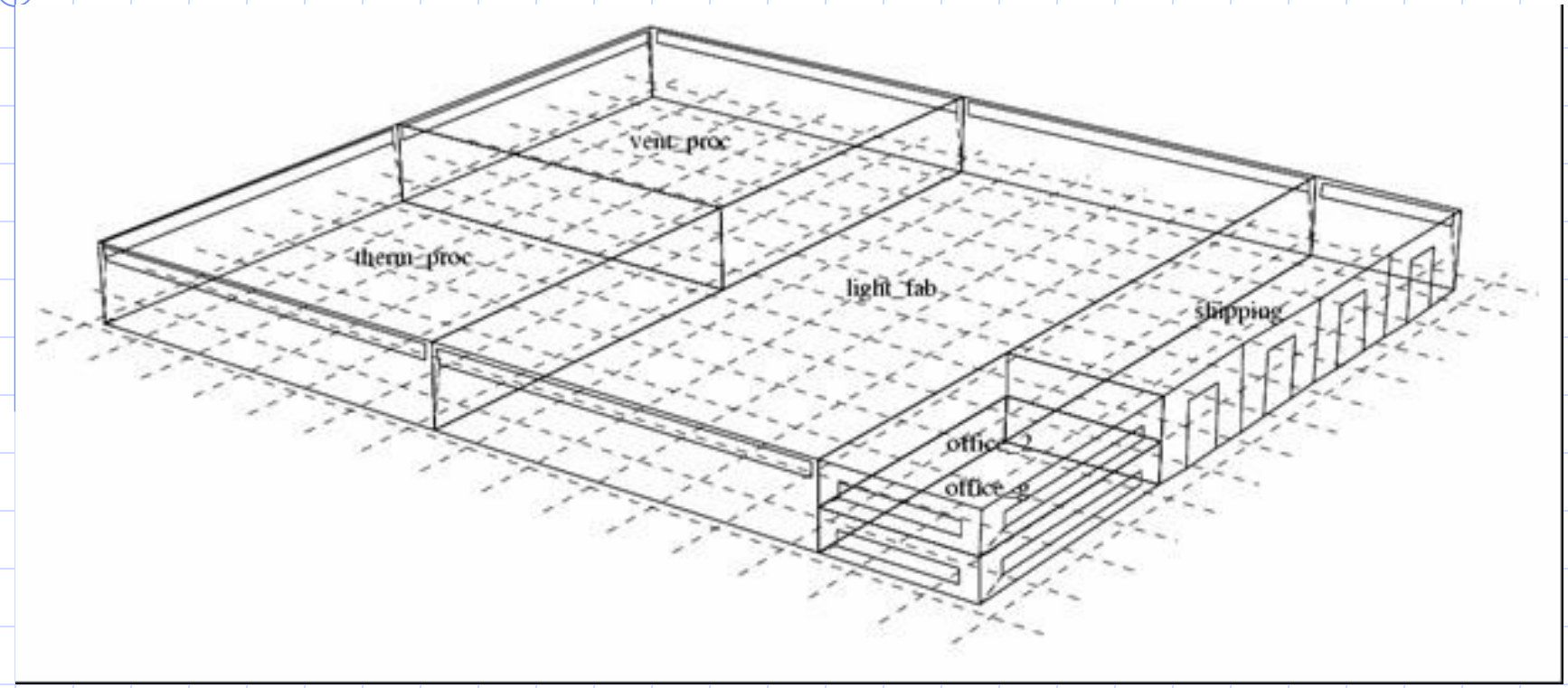
Mechanical System ECMs

Plant Equipment
Thermal energy cold water storage
Thermal energy ice storage
Replace steam/hot water AHU heaters with indirect gas fired heaters
Maintenance
Insulate hot/cold water pipes
Insulate supply and return ducts
Reduce Duct leakage

Internal Heat Gain ECMs

Dimming control for daylight harvesting
Task lighting
Replace existing lights with T8 and instant start ballasts
Occupancy sensors

Industrial building



Building Use

Size (sqft) Total	50000			
Zones	6 zones; 2 office zones, 1 shipping and receiving, 1 high thermal load process, 1 high ventilation load zone, and 1 light fabrication process			
ZONE Office, 2 zones total area	5000			
ZONE Shipping & Receiving	5000			
ZONE Process High Thermal Loads	10000			
ZONE Process High Ventilation Loads	10000			
ZONE Process Light Fabrication Loads	20000			
Height	20' total building height			
Aspect Ratio	200' wide by 237' long, building footprint			

Scheduled Loads

Lighting (W/sqft)

Lighting Schedule	2 Shifts of Operation Process; 8am - Midnight office			
		Operating 1st Shift	Operating 2nd Shift	Non-Operating
ZONE Office	1	100%	50%	10%
ZONE Shipping & Receiving	1	100%	100%	10%
ZONE Process High Thermal Loads	1.5	100%	100%	10%
ZONE Process High Ventilation Loads	1.5	100%	100%	10%
ZONE Process Light Fabrication Loads	1.5	100%	100%	10%

Plug Loads (W/sqft)

Equipment Schedule	2 Shifts of Operation Process; 8am - Midnight office			
		Operating 1st Shift	Operating 2nd Shift	Non-Operating
ZONE Office	0.5	100%	20%	0%
ZONE Shipping & Receiving	0.001	100%	100%	0%
ZONE Process High Thermal Loads	30	100%	100%	50%
ZONE Process High Ventilation Loads	15	100%	100%	60%
ZONE Process Light Fabrication Loads	8	100%	100%	10%

HVAC System

- **Heating**
  - **Gas fired coils**
  - **100% outside air**
- **Cooling**
  - **No mechanical cooling in process areas—ventilation only**
  - **DX packaged units serving offic**es

Qualitative and Quantitative Analysis of ECM

- **Qualitative**
  - **Application:**
  - **Category**:
  - **Description**:
  - **Concept**:
  - **Potential Energy Savings (Qualitative):**
  - **Practical Experience:**
  - **Contacts**:
- **Quantitative**
  - **Potential Energy Savings (Quantitative):**
  - **Simulation Results:**
  - **Major Manufacturers**:

Building Envelope ECMs

- **Solar wall for outdoor air preheating**
- **Cool roofs**
- **Reduce leaks through the building envelope**
- **Vestibules**
- **High-speed roller doors for large openings**

Mechanical System ECMs

- **Displacement ventilation**
- **Setback thermostats**
- **Recirculation with filtration (“economizer cycle”)**
- **Evaporative coolers**
- **High temperature radiant heaters**

Building Use ECMs

- **Daylighting**
- **Turn-off equipment when not in use**
- **Destratification fans**
- **Optimize AHU running time vs. occupancy time**

Process Specific ECMs

- **Balance ventilation and light fabrication shops**
- **Optimal hood design**
- **VFD drives to balance airflow with production rates**
- **Install close capture vehicle exhaust for moving/stationary vehicles**
- **Reduce air flow in paint booths by using variable frequency drives**
- **Energy recovery in paint booths**
- **Heat recovery from air exhausted from heat-treatment ovens**
- **Demand based local exhaust system for welding shops**

Cost Analysis of ECM

- Regional energy costs
  - Gas & Electric
  - High, Medium and Low for each region
- Typical ECM costs include:
  - Material and equipment
  - Labor and maintenance
- Simulation results
  - Compare annual energy use with and without ECM

Payback Calculation

- Simple payback

$$Payback = \frac{\text{Initial Investment Cost}}{\text{Annual \$ Savings}}$$

Synthesizing Results

- Quantitative and qualitative results are incorporated in a standard report format.
- Simulation model parameters are maintained in the Simulation Driver.
- Electronic version of the reports and simulation input files can be e-mailed to experts for critical analysis.

Conclusions

- Developed a methodolgy to evaluate energy conservation measures for government buildings.
- Applied the methodology to three types of government buildings.
- Completed initial analysis of over 20 ECMs for industrial buildings and 15 ECMs for office and barracks.
- Anticipate at least one round of analysis and input parameter tuning.

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Industrial Building Simulation Results

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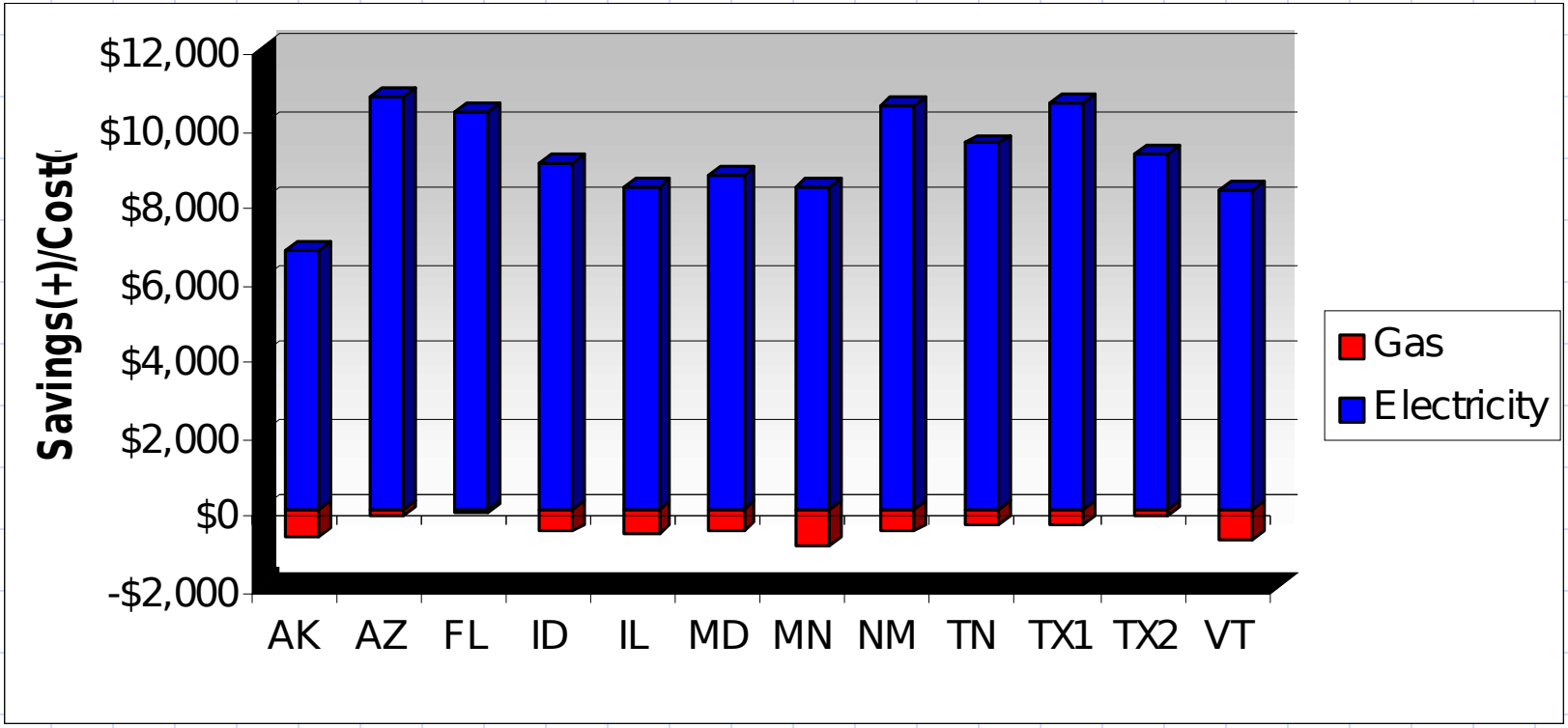
Daylighting

- Base case building
  - Lights ‘ON’ all day
- Modified building
  - automatic dimming controls
  - ‘daylight harvesting’

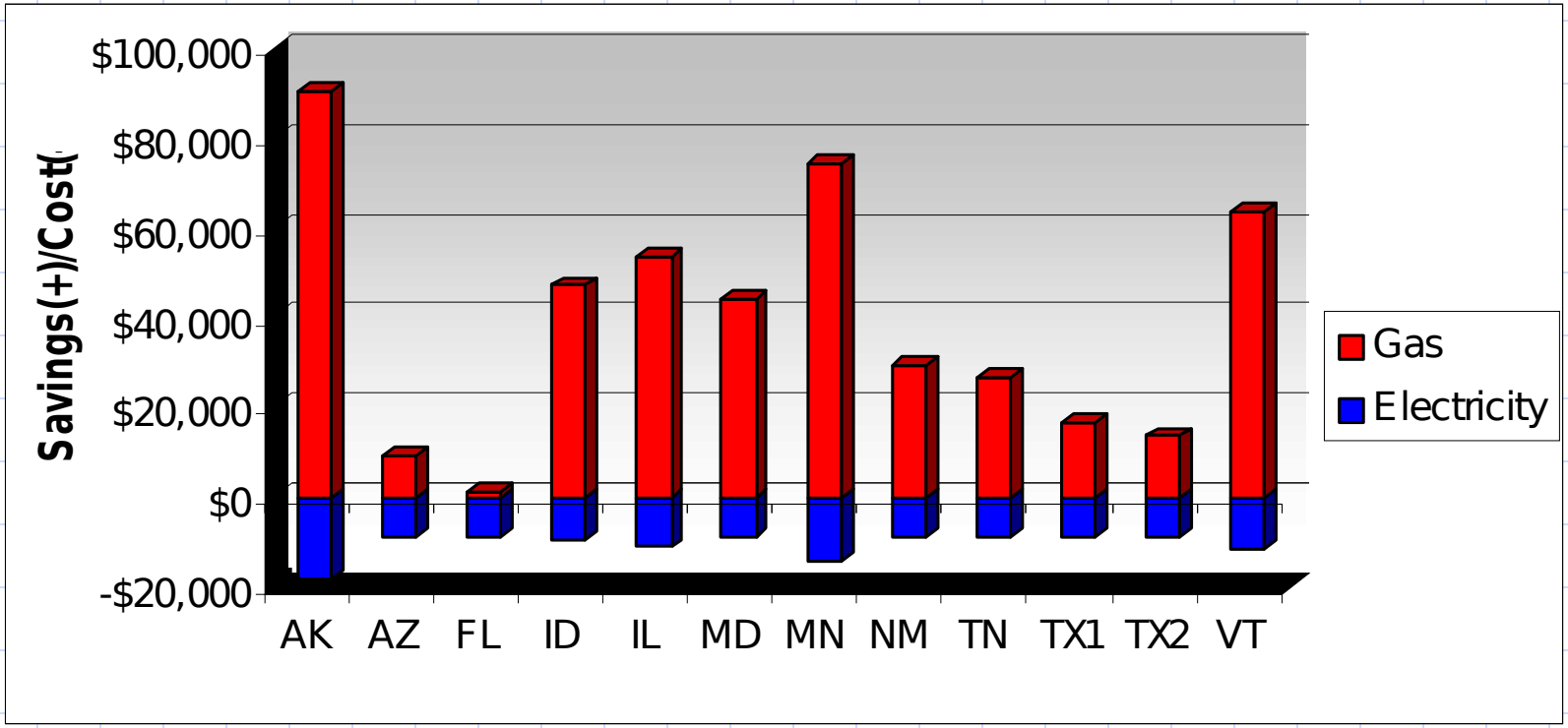
Daylighting



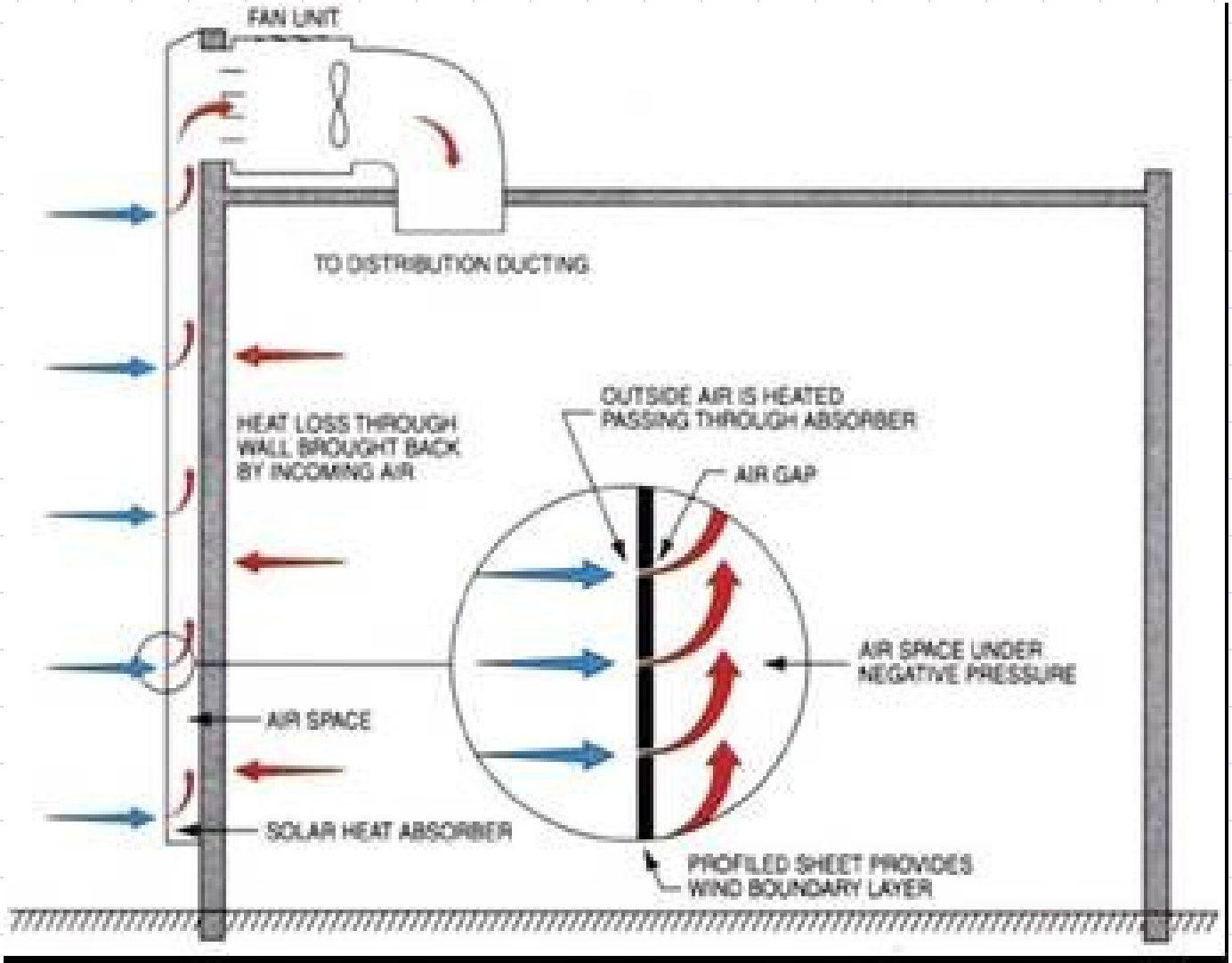
Recirculation With Filtration

- Base case building
  - 100% outside air
  - no filtration
- Modified system
  - mixing box
  - temperature economy cylce
  - high efficiency filters
  - up to 80% recirculation

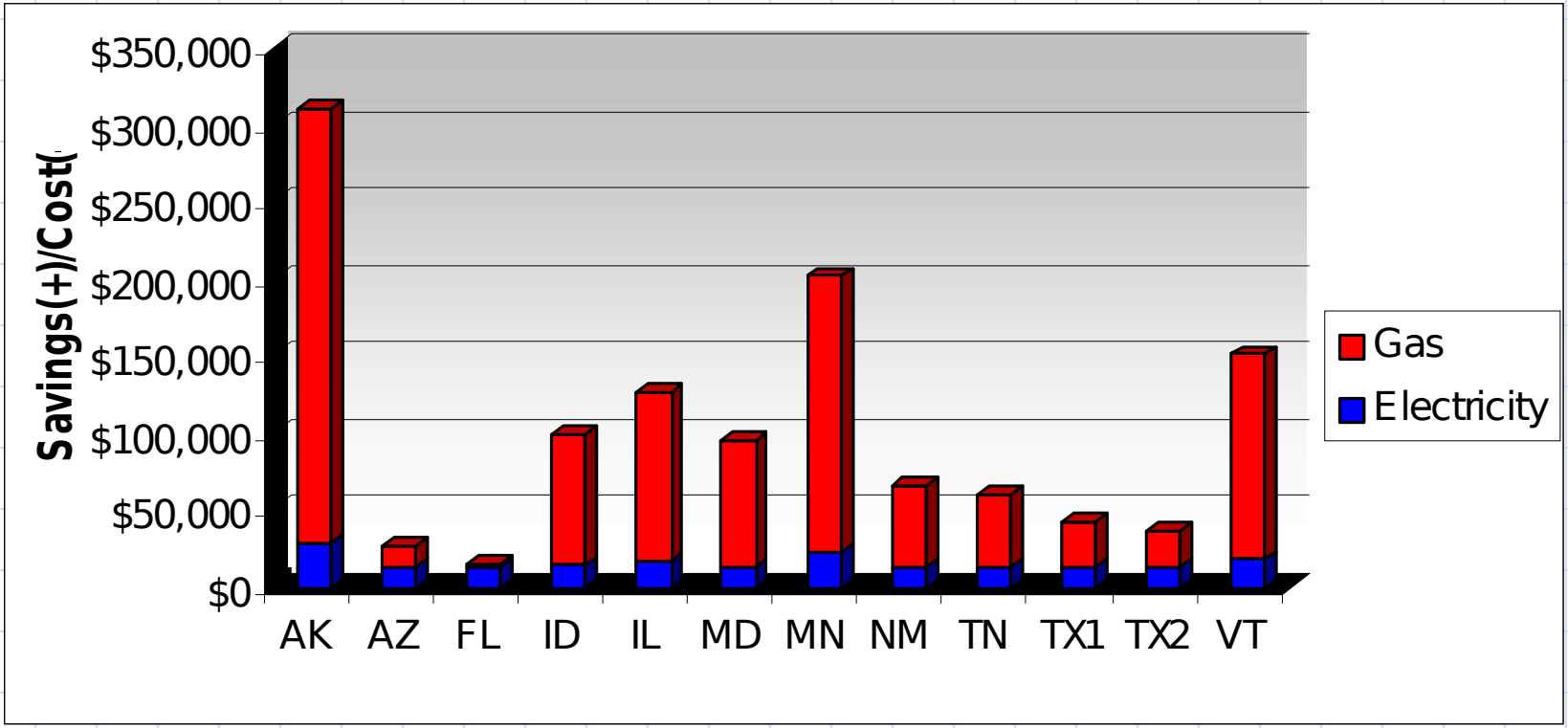
Recirculation with Filtration



Transpired Solar Walls


FAN UNIT
TO DISTRIBUTION DUCTING
HEAT LOSS THROUGH WALL BROUGHT BACK BY INCOMING AIR
OUTSIDE AIR IS HEATED PASSING THROUGH ABSORBER
AIR GAP
AIR SPACE UNDER NEGATIVE PRESSURE
AIR SPACE
SOLAR HEAT ABSORBER
PROFILED SHEET PROVIDES WIND BOUNDARY LAYER

Transpired Solar Wall



Cool Roofs

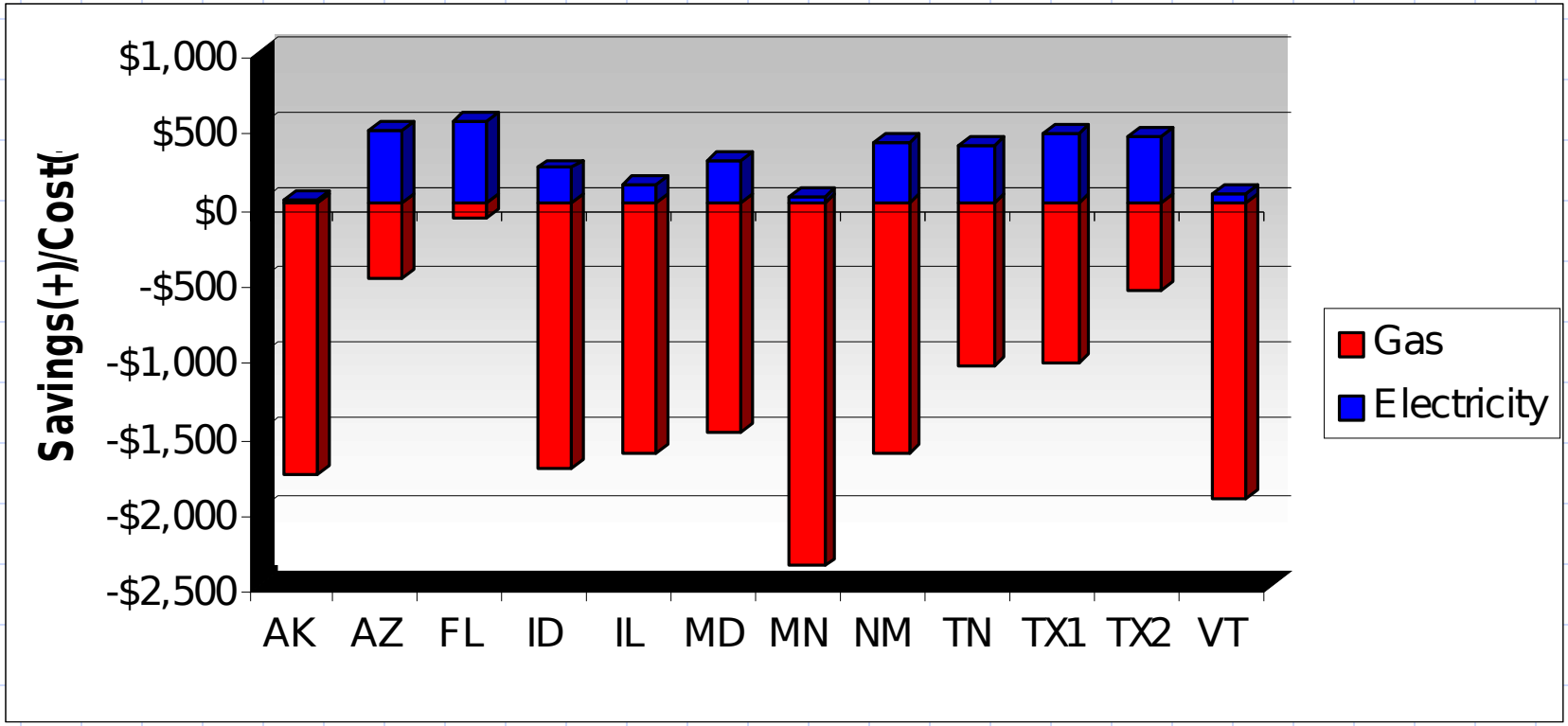
Comparison of competing technologies...

Cool Roofs

LBNL Cool Roof Material Database	**Solar reflectance**	**Infrared emittance**
Sarnafil G410	0.83	0.92
KoolSeal	0.81	0.91
ISP K-711 White ashphalt shingle	0.36	0.91

Technical data differentiating product performance

Cool Roofs


$1,000
$500
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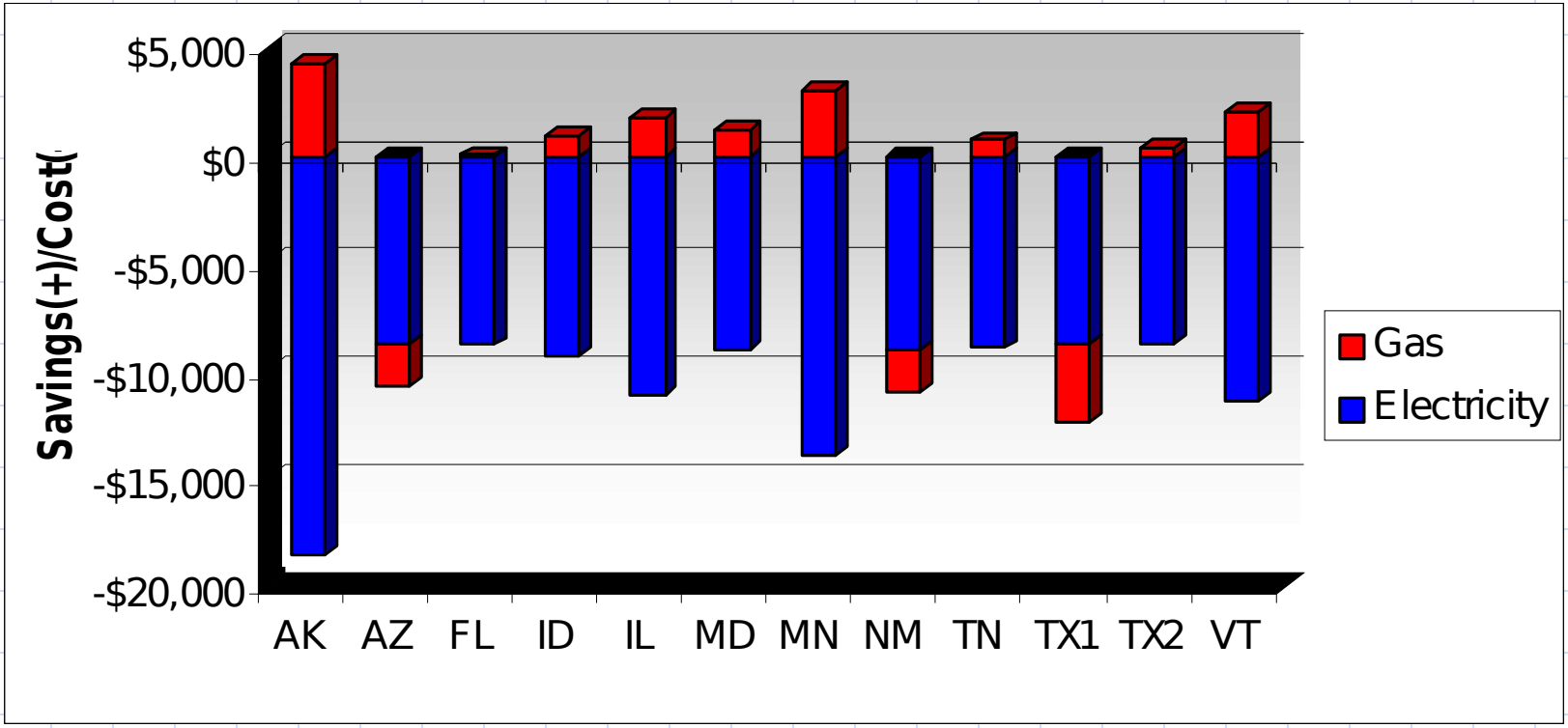
-$500
-$1,000
-$1,500
-$2,000
-$2,500
AK
AZ
FL
ID
IL
MD
MN
NM
TN
TX1
TX2
VT
Gas
Electricity

Direct Evaporative Cooling

- Base case building
  - Ventilation cooling only
  - 100% outside air
- Modified building
  - 100% outside air plus....
  - Evaporative cooling

Direct Evaporative Cooling



Conclusions

- The simulation doesn’t forget the building physics.
- ‘Typical building’ approach does successfully flag promising technologies.
- Building use, climate *and* system type must be comparable for a valid assessment.